constitute failure of the system) or of the impregnants on which radioiodine trapping depends, or even in ignition of the carbon. Tests have shown that deluge water sprays, which are often provided for extinguishing carbon fires, are of limited value.[59] In addition, the water washes out both the impregnant and any trapped radioiodine, thus causing further loss of iodine containment and creating a substantial liquid waste problem.

Demisters are required in all systems because of high sensible moisture and possible steam loadings, which can plug HEPA filters and degrade the effectiveness of activated carbons for organic iodine compounds. Demisters require adequate drains to carry the collected water to the liquid waste system. If drains are not properly designed and maintained, a bypass of the HEPA filters and adsorbers may be created (through the drain system), which would result in failure or degradation of the air cleaning function. Controls, instruments, sensing and air lines, electrical equipment, and electrical wiring that serve the air cleaning system must also be designed to withstand the postulated post-accident environment and conditions without failure. Redundant-unit ductwork and equipment must be geographically isolated, shielded, or installed in individual vaults to protect against single failure from missiles resulting from burst piping or failed equipment and from falling pipes, equipment, and ducts. Redundant units are always required to provide backup air cleaning capacity in the event of on-line unit failure. Provision for remote maintenance, though rarely considered, is desirable to permit the reactivation of failed units or the replacement of damaged or failed components.

### 9.6.4 Control Room Protection Air Cleaning Systems

Control room habitability air cleaning systems are ESF systems that must meet the requirements of USNRC Regulatory Guide 1.52.[58] Unless the internal components (filters, adsorbers) are located at the wall penetration of or within the controlled space, the system is generally of forced-flow configuration and operates in a recirculating mode. In most cases, the air cleaning facilities are external to the control room (controlled space). Positive pressure in the housings and ducts downstream of the fan minimizes in-leakage of potentially contaminated air from building spaces surrounding the control room. Most systems have provisions for obtaining makeup air from outside of the building, with isolation dampers to cut off makeup airflow if necessary. The location of control room protection system components within the control room has the advantage of maintainability under accident conditions; however, its disadvantage is that maintenance operations must be conducted within the control room, an activity that may be untenable to some operators.

The component train of a control room habitability system should include a prefilter, HEPA filter, adsorber, and second-stage HEPA filter or 90 to 95 percent postfilter. Prefilters are recommended even though the system recirculates very clean air, because the lint generated by personnel moving about in occupied spaces can bridge the pleats of HEPA filters, reducing their capacity. Makeup ducts should be fitted with prefilters and one stage of HEPA filters, and should have a high-quality isolation damper to cut off the makeup air in the event of a release of toxic or debilitating industrial gases (e.g., chlorine) in the area of the makeup intake. Redundancy is necessary and is usually provided by two or more totally independent and geographically isolated systems, each capable of furnishing the needs of the control room.

## 9.7 Fuel Reprocessing Plant Air Cleaning

### 9.7.1 Overview

Air cleaning requirements in fuel reprocessing facilities differ greatly from those for power reactors. Basically, the difference stems from the fact that day-to-day operations in a reactor are clean, but day-to-day operations in a reprocessing facility are inherently dirty. In a reactor, air cleaning facilities are designed to accommodate a large radioactivity release under accident condition, whereas the fuel reprocessing facility must accommodate the potential for smaller, but still substantial, releases under normal operating conditions. Effluent air and gases from reprocessing operations are likely to contain substantial quantities of acid or caustic substances that must be removed before they reach the final air cleaning facilities.

There are several lines of containment for fissile material and fission products in a reactor, including the fuel cladding, the reactor vessel, and the containment structures. In a fuel reprocessing plant, however, these lines are all lacking and, although the fuel is handled one rod at a time, the cladding is purposely removed to release the fissile and radioactive materials (under controlled conditions) for processing. In a reactor, fuel is always in an essentially static condition, except when it is being loaded into or unloaded from the reactor vessel or when it is being moved to or from the storage pool. On the other hand, in a reprocessing plant, the fuel and its subsequent byproducts are constantly being chopped, dissolved, leached, or otherwise involved in some active process. The potential for a release of radioactive material or a nuclear criticality incident in the fuel reprocessing facility, therefore, is ever present.

The requirements for design, construction, testing, and maintenance of air cleaning systems for fuel reprocessing and radiochemical facilities differ little from those for reactors. That is, generally the same components (demisters, prefilters, HEPA filters, ducts, fans, dampers, and housings) are employed, and any differences are in the details of application rather than the basic principles of application. Basically, design and installation of air cleaning components and equipment should follow the guides in this handbook. Other guides and standards of particular interest in fuel reprocessing and radiochemical applications include:

- USNRC Regulatory Guide 3.12, "General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants."[37]
- USNRC Regulatory Guide 3.14, "Seismic Design Classification for Plutonium Processing and Fuel Fabrication Plants."[38]
- USNRC Regulatory Guide 3.18, "Confinement Barriers and Systems for Fuel Reprocessing Plants."[39]
- USNRC Regulatory Guide 3.20, "Process Offgas Systems for Fuel Reprocessing Plants."[40]
- USNRC Regulatory Guide 3.24, "Guidance on the License Application, Siting, Design, and Plant Protection for an Independent Spent Fuel Storage Installation."[41]
- 10 CFR, Part 20, "Standards for Protection Against Radiation."[42]
- 10 CFR, Part 50, Appendix P, "General Design Criteria for Fuel Reprocessing Plants."[43]
- ANSI N101.3, "Guide to Principal Design Criteria for Nuclear Fuel Reprocessing Facilities."[44]
- ANSI N303, "General Requirements for Control of Gaseous Effluents Containing Radioactive Material at Nuclear Fuel Reprocessing Facilities."[45]

Air and gas cleaning systems fall in one or the other of two broad categories, ventilation or off-gas. Ventilation air cleaning systems are often very large, as much as 250,000 to 300,000 cfm, although the trend appears to be toward smaller once-through systems. These systems are fed from a number of small branch lines, each of which is generally equipped with at least a HEPA filter at the duct entrance. The central exhaust air cleaning system generally consists of a bank of prefilters and a bank of HEPA filters, although a deep-bed glass fiber prefilter followed by one stage of HEPA filters, or a DBS filter alone with no HEPA filters at the central-exhaust plenum, is used in some DOE installations. Normal off-gas systems are generally small, with airflows that are seldom more than 1,000 cfm, and often 100 cfm. Gases evolved in chemical operations are pretreated by condensation, scrubbing, or other chemical engineering techniques to remove acids, caustic substances, excess moisture, and other materials that could harm filters or adsorbents. In some plants, off-gas exhausts directly to a high stack; in others it is discharged to the central building exhaust air cleaning system to provide series redundancy of the final filtration step.

### 9.7.2 LIGHT WATER REACTOR SPENT FUEL REPROCESSING

The Barnwell Nuclear Fuel Plant was built in the 1970s near Barnwell and Aiken, South Carolina. At that time, it represented the state-of-the-art techniques for ensuring that any release of radioactive material to the environment, under both normal and system upset conditions, would be maintained at levels that meet current ALARA criteria.[66] However, the Barnwell plant has never operated.

Air in operating cells and galleries was designed to be maintained at less than atmospheric pressure so that it would flow from areas of no contamination toward areas of increasing contamination potential. Exhaust air from sources of potential contamination was designed to pass through a duct-entrance filter near the source and then be conducted to the main building or laboratory ventilation system. Air pressure in occupied areas and aisles was to be maintained at slightly higher than atmospheric pressure. All ventilation air was to be exhausted through one of two ventilation air cleaning systems equipped with a single bank of HEPA filters, then to a 100-m stack. Most first-stage duct-entrance HEPA filters were to be changed remotely, but radioactivity levels at certain low-activity cells and at the central building-exhaust plenum were expected to be low enough to permit contact maintenance. The quantities of radioisotopes in the ventilation air streams were estimated to be relatively insignificant under normal operating conditions. Ventilation air for fuel receiving and storage areas was designed to be independently supplied and exhausted directly to the atmosphere or recirculated (through roughing filters only) without additional treatment, since no contamination was expected at these points.

Off-gas from the shear and dissolver was designed to be passed through a dust screen to remove large particles, through a condenser to remove most of the water and soluble contaminants, through a mercuric nitrate-nitric acid scrubber to remove noncondensable iodine, through a vapor-liquid phase separator, and finally through an absorption column where nitrogen and nitrogen oxides would be oxidized with air and absorbed in water. This dissolver off-gas stream would then be discharged to the main process vessel off-gas (VOG) system. Although the nitric acid and iodine content of gas entering the VOG system should have been quite low; an additional iodine scrubber was provided. The VOG system, consisting of a condenser, a vapor-liquid phase separator, a second iodine scrubber, and a gas heater, then would exhaust to the stack through an air cleaning unit equipped with HEPA filters (two stages) and zeolite-filled adsorbers. No provision was made for trapping or removing the noble gases. It was proposed that, after pretreatment and passage through one stage of HEPA filters and adsorbers, the VOG stream should be discharged to the building-exhaust air cleaning system. For reasons given earlier, a second stage of HEPA filters should have been provided downstream of the adsorbers.

### 9.7.3 NEAR-ZERO RELEASE CONCEPT

In the past, radioactive discharges have been limited to quantities that would yield concentrations of radioactive contaminants at site boundaries well below the levels set by national and international agencies for continuous intake by the public.[42] The present emphasis is to ensure that releases of radioactive material are also at ALARA levels. It is believed that reductions in effluent activities and volumes to levels approaching near zero can be achieved in future facilities. The near-zero confinement objective can be realized by a reasonable projection of the technology currently in development. Although the related process development work is not complete, it appears that the following retention factors can be attained: iodine – $10,^{10}$ noble gases and tritium – $10,^{5}$ and particulates – 10.[16, 68]

If liquid metal fast breeder reactors (with their higher burnup levels, higher specific power, and economic incentive to reduce spent-fuel preprocessing decay time) assume a role in the power economy of the future, the input level of fission products to reprocessing plants will increase significantly. This higher input level of activity, coupled with possible reductions in the permissible release of activity to the environment, will place very stringent demands on effluent control systems and require advanced processes for the control and removal of the volatile fission products from effluent streams. The current practice of using once-through ventilation for cell enclosures at rates in the 100,000-cfm range is not compatible with the near-zero release concept of activity from the plant. Removal of trace concentrations of tritium, krypton, and iodine from very large air and gas flows is economically infeasible as well as technically unsound.

Key factors in reducing the quantity of radioactivity released to the environment to near zero include a reduction in the volume of effluents, low air in-leakage into cells, and avoidance of bypassing the contaminant trapping systems. The practical extent of the treatment of an effluent is determined in large measure by the volume of the effluent to be treated. A large shielded fuel examination facility (the High-Level Fuel Examination Facility at the National Reactor Testing Station in Arco, Idaho) is operating with an air infiltration rate of 0.004 cfm. It is believed that a practical infiltration rate for a 5-tonne/day reprocessing facility, designed for near-zero radioactivity release, is 100 cfm or less. To meet these objectives, a high degree of overall containment must be maintained during all phases of plant life, including routine operation, maintenance, and decommissioning at the end of the plant's useful life.

## 9.8 REFERENCES


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